MOBILE RELAY (REPEATER) APPLICATION MANUAL

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THE MOBILE RELAY APPLICATIONS MANUAL

INTRODUCTION

This manual has been prepared for the land-mobile sales/service company which has not yet done much work with mobile relay stations.

It is intended to present some of the sales, licensing, and engineering information needed for implementing mobile relay stations, with particular emphasis on the Micro-Com U10R repeater station.

WHAT IS A MOBILE RELAY STATION, AND WHAT IS A REPEATER STATION:

The term "repeater" has become the generally used term for a radio transmitter-receiver combination that receives radio signals on one radio frequency, and retransmits them on another frequency. When a repeater is used to retransmit the messages from mobile stations, the FCC rules call it a "mobile relay." When a repeater is used to retransmit messages between fixed stations, it is called a "fixed relay" in the rules. The Micro-Com U10R repeater may be used in either mobile relay or fixed relay applications.

BLOCK DIAGRAM OF A MOBILE SYSTEM:

Figure 1 is a block diagram representation of a 450 MHz band mobile relay (repeater) system, with typical frequencies of operation being shown.

The block diagram shows a repeater system, which is often

located atop a high hill, mountain, or building; a control station, which is the location of the system dispatcher, and two mobiles. The system could, of course, have more than one control station, and almost any number of mobiles. Often, hand carried portables are used on repeater systems instead of, or in addition to, the mobiles.

In the example shown in the block diagram, all of the mobiles and the control station transmit on 469.50 MHz, and receive on 464.50 MHz. The repeater has just the reverse frequency arrangement; it transmits on 464.50 MHz, and receives on 469.50 MHz. The separation between the two frequencies is exactly 5 MHz. This is the standard frequency spacing for repeater stations in the 450-470 MHz band in the United States.

THIS IS HOW THE SYSTEM OPERATES:

When one of the mobiles (or the control station) transmits on 469.50 MHz, it is received by the repeater station's receiver. The receipt of the signal turns on the repeater station transmitter, which retransmits the information on 464.50 MHz. Since the receivers in the mobiles (and the control station) are all tuned to 464.50 MHz, all of the other mobiles (and the control station) hear the original message in their receivers.

As you have probably already observed, the typical range obtained between two mobiles is considerably less than the coverage range between a base station and a mobile. This is true on both

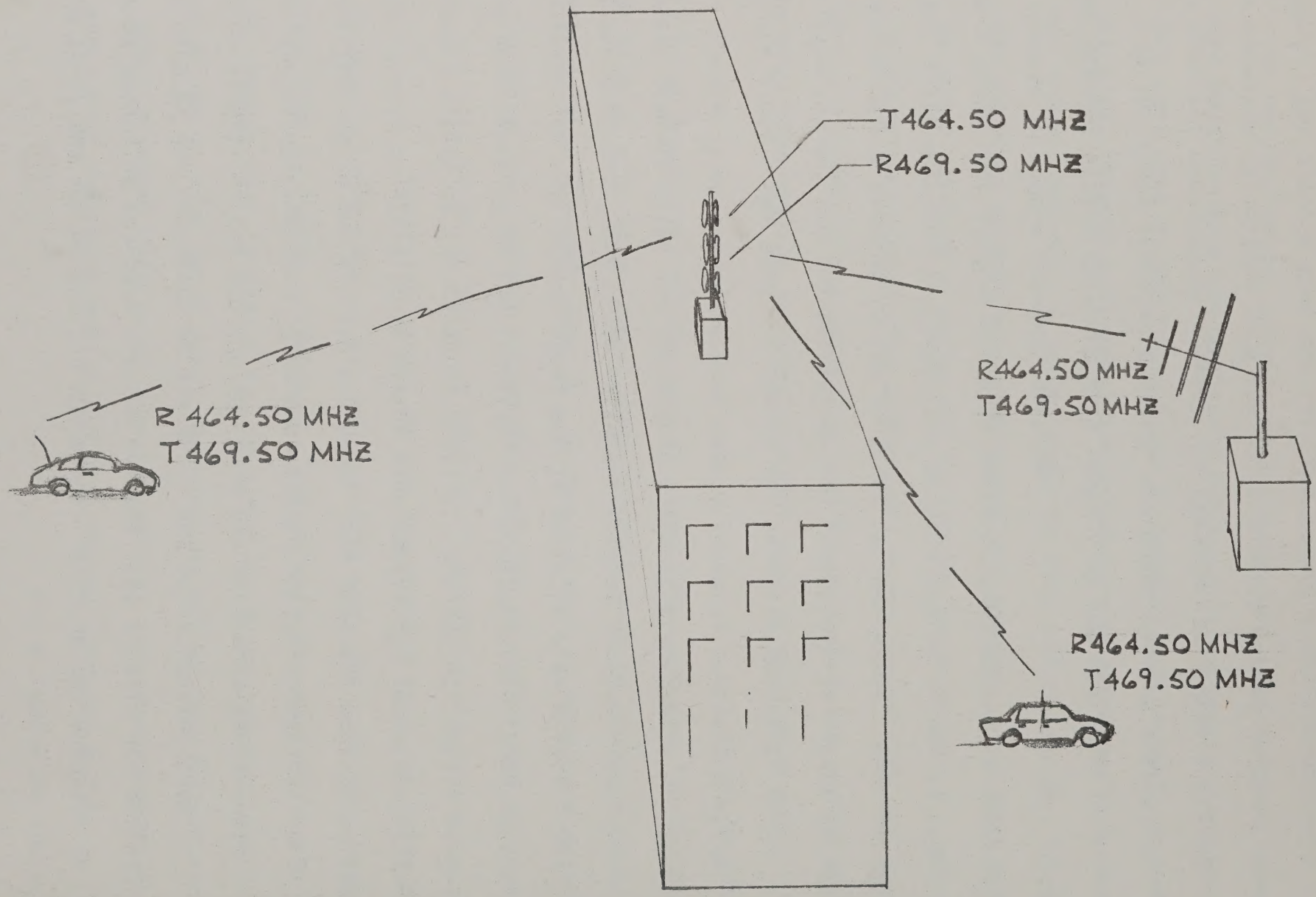
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FIGURE 1

the 30-50 MHz and on the 150 MHz bands. Without the superior antenna height of the base station antenna, the signals are quickly blocked by the curvature of the earth and other obstructions. Since signals in the 450-470 MHz band are even more susceptable to terrain obstructions, direct mobile-to-mobile communication is very limited in the 450-470 MHz band. The repeater station solves all of this by effectively giving each mobile the advantage of the antenna height of the repeater station. Because all mobile signals are retransmitted by the repeater, any mobile within range of the repeater can talk to any other mobile which is also within range of the repeater. For those customers needing excellent mobile-to-mobile communication you can't beat a repeater system.

You will note that we have been discussing repeater systems in the 450-470 MHz band. Although the repeater principle works in other bands, FCC regulations do not permit mobile relays in the Business Radio Service in the 30-50 or 150 MHz bands. Some of the other radio services are permitted to have mobile relays in these lower bands, but finding suitable pairs of frequencies is usually difficult in todays crowded spectrum.

TONE CONTROL VERSUS NOISE SQUELCH CONTROL OF THE REPEATER:

In the first repeater systems, the noise squelch system of the receiver was used to operate the transmitter. When a signal was received, a voltage from the noise squelch turned on the transmitter. The circuit that did this was termed a Carrier Operated

Relay, or simply a COR.

As the channels became used by several licensees in an area, it became clear that it just wouldn't do to have repeater transmitters popping on the air whenever their noise squelch was opened by any transmitter on the channel. As a result, tone systems were used to actuate the transmitter. Although a number of tone systems have been used for this purpose, the use of tone squelch (CTCSS) systems for this purpose has become almost universal.

Unless the repeater is located at least 75 miles from any station authorized to use the same mobile channel, FCC rules require some form of tone actuation. In some sparsely settled areas, it is possible to find channels which comply with this 75 mile requirement, and the extra costs of tone may be eliminated as an economy move.

The most typical tone actuated repeater systems work this way: All mobile stations (and control stations) are equipped to transmit the appropriate CTCSS (Continuous Tone Coded Squelch System) tone. A tone squelch decoder in the repeater station, tuned to the same tone, detects the presence of the tone on received signals. If the proper tone is received on an incoming signal, the repeater turns on, and stays on until the tone ceases. Most repeater systems also transmit a CTCSS tone, and in this case the associated mobiles (and control stations) are also equipped with tone decoders that prevent unwanted signals (those without the

specific CTCSS tone) from bothering the operators.

THE COMMUNITY REPEATER:

Since the repeater station is the most expensive component of a repeater system, and since a repeater station can be used by a number of licensees, it was natural that some of the users of two way radio would want to get together and share the cost of a repeater station. By combining the use of the one repeater they could cut the costs of their communication system, or they could afford to spend more on a higher antenna tower for better coverage, (or obtain some of both benefits). Thus was born the "Community Repeater" concept. Two, three, or more licensees could share the cost of one repeater station, and all could use it.

The Community Repeater has become very popular in the larger cities. In such cities, a number of licensees must share each radio channel anyway, so why should each undertake the expense of constructing and maintaining their own repeater station? In these cities, the repeater stations are usually located atop the tallest buildings, and rental charges for the space on these buildings are often very high--sometimes too high for one licensee to foot alone.

In Community Repeaters, it is common practice to have a different CTCSS tone for each of the licensees using the repeater. In this way, each fleet does not hear the transmissions of the other fleets using the repeater. Of course, only one fleet can use the repeater at a time, and anyone wanting to make a

transmission should "monitor" the channel first.

The Micro-Com U10R repeater normally comes equipped with the necessary modules for one CTCSS tone. Added tone modules may be plugged in to provide up to seven different CTCSS tones--making it possible to have as many as seven different companies sharing the repeater. The U10R can also be operated in the noise squelch operated mode (i.e., without tone).

THREE MINUTE TIMERS, DROP OUT DELAYS, AND ALL THAT:

When a repeater station is operated by noise squelch--i.e., without tone control, the FCC requires a timer that will automatically turn the repeater transmitter off after three minutes of continuous operation.

The Micro-Com U10R comes equipped with such a timer, adjusted to a little under three minutes for compliance with this rule.

The three minute timer serves a useful function in tone equipped systems, such as the Community repeater, because it helps prevent one fleet from monopolizing the channel. After a mobile has held the repeater on for almost three minutes, a short "beep" note is transmitted and the repeater transmitter is turned off. The timer automatically resets as soon as the mobile goes off the air and another one (or the same one) comes back on.

The "drop out delay" is another standard feature of the Micro-Com U10R. After each mobile transmission, the repeater transmitter is held on the air for about three seconds. When a continuous

group of transmissions between mobiles is in process, with no more than a three second gap between them, the repeater transmitter just stays on the air. This drop out delay feature is quite useful to the users of a repeater. When a driver is out at the fringes of the station coverage, he can determine whether he is in a good spot to call in; he just clicks his mike on for a couple of seconds and releases it. If he hears the repeater coming back to him he knows he is in a spot where he can call in. By listening to the quieting on the return signal, he can maneuver his car into an optimum location for communication. Drivers make a lot of use of this feature, once they understand it. Also, they will use the feature to assure themselves that their radio, and the repeater are functioning.

For applications where they are not wanted, the three minute timer and the drop out delay feature in the Micro-Com U10R may be easily disabled.

TECHNICAL ADVANTAGES OF THE REPEATER SYSTEM:

Since this is being written for dealers who have been primarily engaged in the sales of systems in the 30-50 MHz and 150 MHz bands, let us consider a comparison of 450 MHz mobile relay system performance versus 30-50 MHz and 150 MHz system performance.

First, of course, all Business radio allocations in the lower bands are on a simplex basis--that is each mobile and each base station of a radio system operates on the same channel. Thus, it

follows that each base station, and each mobile, transmits and receives on the same channel. Each mobile on a given system can talk directly to any other mobile on the system, and to any and all base stations on the system.

This raises one of the major problems with 30-50 MHz and 150 MHz systems--base-to-base interference. Even though the nearest user of your radio channel may be some 80 or more miles away, you are likely to hear his base station transmissions on your base station receiver. Although tone squelch can eliminate some of the bother of listening to the other base station, this base-to-base interference is often so strong that it blocks out the reception of your own mobiles. To make matters worse, the other base station may not even know when some of your mobiles are transmitting. Even though the base operator may be courteous enough to monitor before transmitting, he may often inadvertently break up one of your communications. This becomes even more of a problem on low band when the "skip" is rolling in. In many areas of the country, tropospheric conditions make the problem serious for high band systems also.

The technical reason for the severity of base-to-base interference is that base station antennas are typically much higher than mobile antennas. If the system is intended for much coverage, antenna heights above 100 feet are common, and the range between two 100 foot antennas is much greater than the range from a 100

foot antenna to a mobile.

Now, take a look back at the repeater block diagram in Figure 1, and imagine another repeater system using the same channel pair, but located some 80 miles away. Notice that the receiver of one repeater station is not on the same channel as the transmitter of the other repeater station. When the repeater station in the first system is transmitting, it will not be heard in the receiver of the other repeater station. Regardless of the height of the antennas, the two stations will not hear each other. The only way that interference between systems can occur is if the mobiles (or control station) of one system are within the coverage area of the repeater station of the other system. (We are substituting the term "repeater" for the term "base" in this discussion to keep our definitions straight. Although the "repeater" station performs much the same function of the "base" station, there is no "base" station in the repeater system described.)

Thus, we get to the first big plus for the repeater system: There is no counterpart to the base-to-base interference problem that plagues users of the lower bands.

While we are on the subject of interference, we can mention a couple of plusses that follow just from the fact that we are thinking about the use of the 450-470 MHz band:

(1) Ignition interference is much less than on the lower bands. (2) Especially in the areas outside the larger cities,

the population of stations per channel is much less in the 450-470 MHz band. If you are some distance from a big city, you can probably find several channels that are completely empty--just imagine--a channel all to yourself!

The most important advantage of the repeater system is that it provides the best mobile-to-mobile communication available.

With simplex systems, mobile-to-mobile communication must be obtained on a direct basis; if mobile A wants to talk with mobile B, the two mobiles must be located within range of each other. Even with high power mobile transceivers on low band, a reliable mobile-to-mobile range of 25 miles is stretching things quite a bit. On the other hand, a ten watt repeater system (using ten watts of power at the repeater with typical antenna gain, and ten watts of power in the mobiles), with a 150 foot antenna tower can yield mobile-to-mobile communication over a circle having a diameter of some 60 miles. By using greater antenna heights, and mobile gain antennas, this simple 10 watt system can give even greater reliable ranges. If you happen to have a mountain in your back yard that rises a couple thousand feet above the average terrain, you can get a coverage area some 80 miles in diameter--all with the 10 watt system!

This good mobile-to-mobile communication is of great importance to the manner in which small businessmen use their radio systems. In many cases, supervisory people are out in the field

in automobiles much of the time--going from one job to another. They need to be able to talk with other workers in their vehicles, and with their office. The repeater gives them the solid contact they need, and avoids having to obtain verbal repeats from the main office operator. The main office can even be closed and mobiles can talk from one end of the service area to the other.

Quite a few other benefits arise from the fact that you can always hear the other mobile. This makes the system pretty much a party line--everybody can hear what everybody else says. Even though a given communication may be from the control station operator to a specific mobile, all the other mobiles know what is said on both sides. This helps tremendously in coordinating the work of the fleet. It prevents misunderstandings and bruised feelings between drivers, which can occur when a driver hears only one side of a conversation with the office. Many users report a great improvement in the spirit of cooperation between their personnel when they use a repeater for the first time.

This thing about company spirit and cooperation may sound like just sales talk--it isn't! One of the best ways to get into selling repeater systems is to install one for your own sales or service fleet. You will learn first hand of the benefits, and will have something to show your prospective customers. It is really impressive to seat your prospective customer in your car, and listen to your own repeater system functioning. It impresses the

customer about the quality of communication you are offering. If your own radio operation is truly businesslike, he will be impressed by your company's capabilities and efficiency.

ECONOMIC ADVANTAGES OF THE REPEATER SYSTEM:

If a customer needs a substantial coverage area--say something more than a 15 or 20 mile radius from his office, you can usually give him what he needs at lower cost by use of the repeater type of system---IF you have a community repeater system to put him on.

In the simple base-and-mobile type system, the tower is usually located right at the customer's office location or at some remote site, and the base station is controlled by rented telephone pairs. It is usually impractical to use the tower for a number of customers, because distance factors and the monthly costs of remote telephone lines add up. With the community repeater, however, a number of customers can share the costs of the repeater station and the tower. Because the community repeater will be controlled by a "control station" at the customer's office, no leased wire lines are needed, and the customer's office can be at almost any distance from the repeater station. If the customer should move his office--and the smaller businesses do move frequently--you don't have to plan a tower move. It is often as simple as picking up the control station and plugging it in at the new location.

THE REPEATER STATION AS A MONEY MAKER FOR THE SALES AND SERVICE COMPANY:

If you have been doing most of your business in base-and-mobile systems in the 150 and 30-50 MHz bands, you will find new opportunities for profits in 450 MHz repeater systems--and at the same time you will be giving your customers more value for their communication dollars.

One profit making opportunity is the rental of space in a multiple transmitter site. The site could be a leased space atop a high building, a mountain top facility, or simply a high tower strategically located to cover a specific area. Since the repeater station need not be located at, or even close, to the user's business location, it can be located at a site that will best cover the user's area of interest. In a given community, most of the business people will want to cover somewhat the same area. Provide them with a common site that covers this area nicely, and rent out space for transmitters and antennas. Your rental charge can be well below what it would cost each customer to provide his own site--but if you have several customers using the site you can show a neat profit on it.

Another profit making opportunity comes from ownership of the community repeater station itself. If you have several customers sharing a single community repeater, you can charge a monthly rental fee for the equipment that shows a tidy profit to you, yet

results in a charge to the customer that is well below what it would cost him to provide his own equipment. Most dealers charge an equipment rental that includes the site rental, the equipment, the power it consumes, and a flat fee maintenance charge in a single billing. In order to steer clear of the FCC rules, you should not share in the usage and should not be one of the licensees of any repeater that you rent to others. (All of this will be covered in a future section on licensing matters--for now, you should understand that each one of the users sharing a particular repeater should have a license for operation of that station.)

The big money making advantages come from the ease of selling a repeater system, and keeping it sold. Once you have the first repeater station going at a given site, you can learn exactly what areas it covers. You can make a coverage map and tell your customers that the system you are proposing to sell to them will cover that area. You don't have to make promises on guesswork. If the customer will go for a ride with you, you can show him what coverage he is buying. This added confidence makes it a lot easier to get that signature on the order blank. Radio is still somewhat a mystery to the typical prospecitve customer, and being able to tell him "what you see is what you get" is a great help. Keeping a system sold is as important as selling it in the first place. Since the customer has no coverage disappointments when the system is actually installed, he won't be coming back saying it won't do

his job. Since the system is easier to sell, it takes less selling time, so you make more profit on the sale. If you have ever had to "swallow" a system because it didn't give the expected coverage when installed, you know how important keeping the system sold can be to your profit picture.

A lot of times, one of your customers on a community repeater will bring in another company that would make a compatible "sharee." This happens a lot in the construction trades--a plumber, an electrical or general contractor do a lot work together, and may find it convenient to share the same repeater. Your customer does the selling for you--you just write up the order!

If you have a community repeater available, with the equipment on a rental basis, the cost of "getting started" can be quite small for the new customer. All he needs is a control station, with a simple installation, and a few mobiles. No base station, tower, antenna, and all that. The "entry fee" is smaller, so the sale is easier to close.

If your company is large enough to hire a number of outside salesmen, you will find that the easier selling of the repeater system will reduce your costs of training new salesmen. They don't have to be technical enough to make sensible coverage estimates for each customer, and they won't be promising the moon when they shouldn't. By using, and demonstrating, the repeater system, they know what the coverage is. They know the cost of each item of the

system. They don't have to figure variables such as towers, telephone control lines, and all that. They can just quote the standard package most all of the time, and call for help only if a customer's need won't fit into the repeater package.

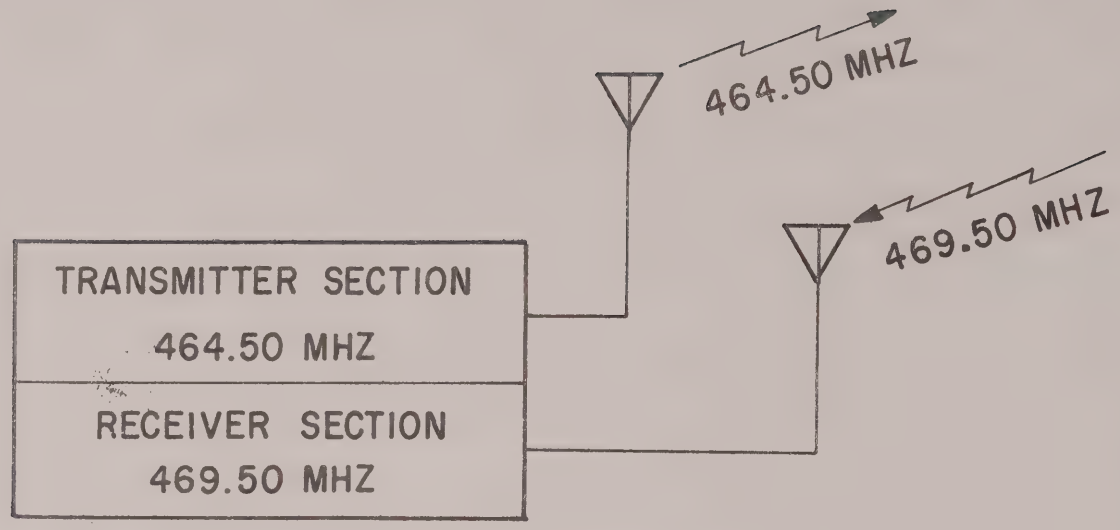
ANTENNA SYSTEMS FOR REPEATERS (Mobile Relays)

We are going to assume that this is your first repeater installation, and give you information from that point of view. If you are an old hand at this sort of thing, you can skip over the elementary stuff.

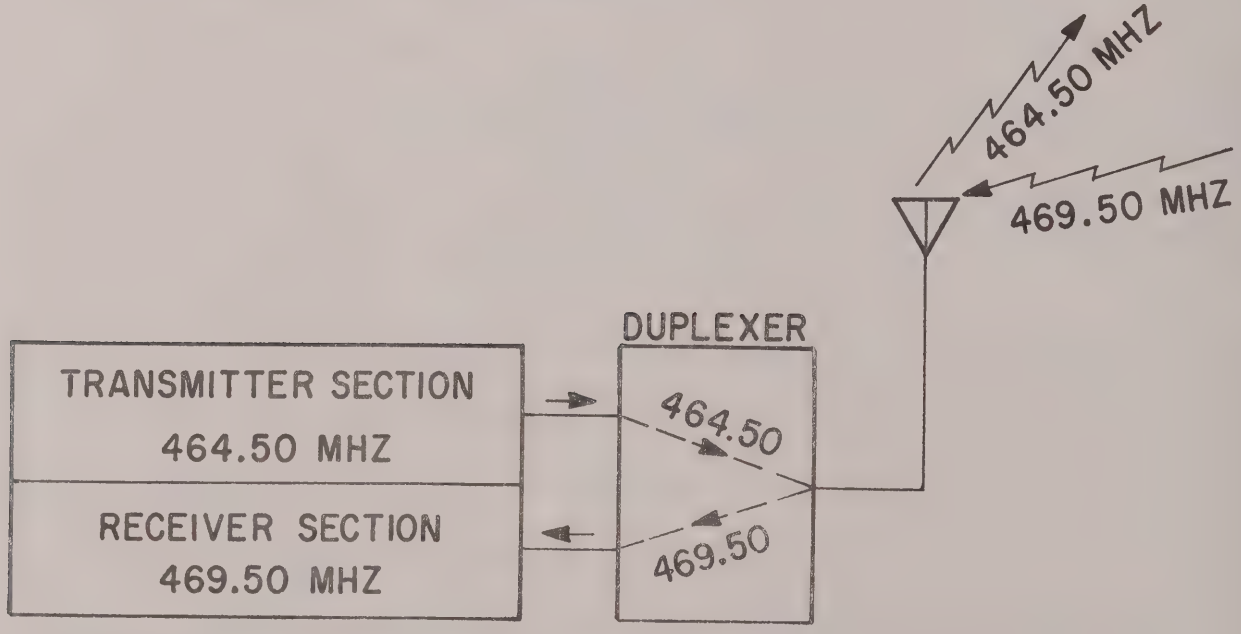
The considerations for selecting an antenna system for a repeater system are the same as those for a base station antenna system--with some important additions.

As with any base station installation, we will need sufficient antenna height; we will want to obtain some power gain through the use of a gain type antenna; and we will want to select an antenna cable that gets the bulk of our transmitter power to the antenna.

Since the repeater is to operate in the 450-470 MHz band, we would want the antenna height to be somewhat more than we would use for comparable coverage in the lower frequency bands. Since antenna gain is more economically available in the 450-470 MHz band than in the lower frequency bands, we will probably use a high gain antenna. And, since losses in coaxial cable are greater at 450 MHz, we will need a higher grade coax on our line. But all of these considerations are the same ones we would use on the



REPEATER USING SEPARATE ANTENNAS
FOR RECEIVE AND TRANSMIT



REPEATER USING SINGLE ANTENNA
WITH DUPLEXER

BASIC REPEATER ANTENNA SYSTEMS

FIGURE 2

installation of a 450 MHz base station, as compared to a base station for the lower bands.

The big difference with the repeater station is that the transmitter and receiver run simultaneously whenever someone is using the station. For this reason, we can no longer switch a single antenna from receiver to transmitter as we do in a base station or a mobile. We have to provide separate antennas for the transmitter and the receiver, or we have to figure out a way to use a single antenna for both functions. Both methods are used: Some repeaters use separate antennas, and separate coaxial feeds for the transmit and receive functions. Others use a single antenna, with a device called a "duplexer" which enables the same antenna to be used for both receive and transmit functions simultaneously. A block diagram of these two methods are shown in Figure 2.

Now that we have provided for simultaneous antenna service to transmitter and receiver, we have an additional factor to watch in the repeater station: we have to be sure that the transmitter does not interfere with the receiver. At first glance, this shouldn't seem to be a problem--after all the transmitter and receiver frequencies are 5 MHz apart, and it would seem that our receiver selectivity should be sufficient to reject something 5 MHz away. Not so! When we attempt to have a transmitter delivering 10 watts running right next to a receiver detecting signals as low as 2½ milli-micro-micro-watts, (that is the power in a .35 microvolts signal

at the 50 ohm coax), we must take special precautions to avoid interference.

There are two primary ways in which the transmitter can interfere with the performance of the receiver of our mobile relay:

1. The transmitter carrier itself may be present at the receiver antenna input at a sufficient level to create limiting in the early stages of the receiver. This reduces the gain of the early stages, and thus reduces the sensitivity of the receiver. This form of interference is called "Transmitter Carrier Desensitization."
2. Every transmitter (even ones built by Regency!) emits a spectrum of noise at frequencies close to the transmitter channel. This noise is greatest at frequencies closest to the transmitter channel, and falls off at frequencies farther from the the transmitter channel. Some of this noise falls within the channel to which the receiver is tuned, and looks like thermal noise to the receiver. This form of interference is called "transmitter noise interference."

In addition to these two, there are a multitude of other ways in which interference might develop: One of the spurious emissions from the transmitter might fall at the same frequency as the receive channel, or one of the receiver spurious might fall on the transmitter channel. Or, the transmitter frequency might beat with

some incoming signal to create an intermodulation product that falls on the receive channel. In a site where a large number of transmitters are located, these types of problems may take careful analysis to eliminate. We are not going to get into them here, because the solutions to multiple transmitter site problems could fill a good sized book. This section is devoted to telling you how to get your first repeater going smoothly. If you add another one at the same site, your chances of any problems other than the primary ones are slight. As you add the third, the fourth, and more transmitters, you will need to become acquainted with the other forms of common site problems and how to cope with them.

Now, back to the primary interference problems mentioned above, namely transmitter carrier desensitization and transmitter noise interference. If we used the two-antenna system shown in Figure 2, and located the transmitter and receiver antennas very close together, the receiver antenna would pick up a lot of the energy radiated by the transmitter antenna. Our repeater systems would not work, or would work very poorly, because of the two types of interference: The transmitter carrier, at 464.50 MHz would be received so strongly by the receiver antenna that some of it would pass through the input tuned stages of the receiver and create limiting that would seriously degrade the receiver's sensitivity. (In high powered systems, enough power might be transferred to burn out parts of the receiver input---the degradation, in such case, would

be permanent, until repairs are made!)

Assuming that the antennas are spaced just far enough apart to avoid the transmitter carrier desensitization of the receiver, we are still not out of the woods. The receiver antenna would still receive the transmitter noise spectrum, and some of this noise would fall within the 469.50 MHz channel to which the receiver is tuned. The receiver would not be able to distinguish this noise from ordinary thermal noise, and instead of operating at its expected sensitivity, the receiver might require several microvolts of incoming signal to operate.

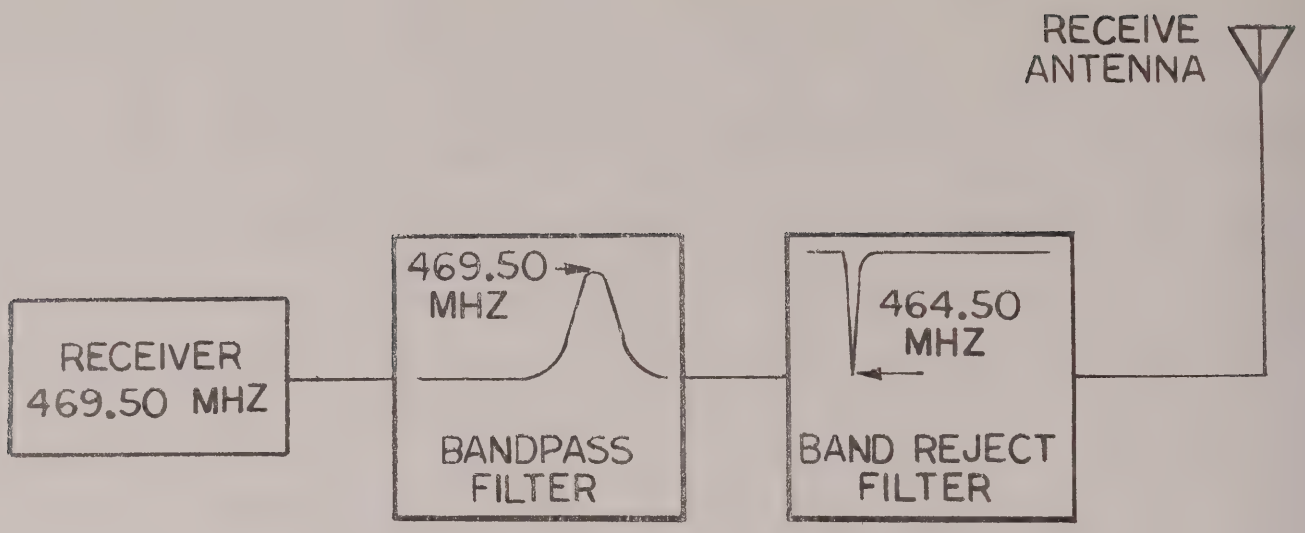
Both of these types of interference could be eliminated by merely spacing the antennas far enough apart so the receiver antenna picks up a suitably small amount of energy radiated by the transmitter antenna. We might place one antenna considerably above the other one on a tower (vertical separation), or we might locate the two antennas on separate towers but at the same height (horizontal separation). Since the antennas radiate (and receive) best in the horizontal plane, a given amount of vertical separation does the job much more effectively than the same amount of horizontal separation.

Even with vertical separation, however, it may be inconvenient to provide enough spacing between the antennas to eliminate either (or both) "transmitter carrier desensitization" or "transmitter noise interference" in the receiver.

For this reason, when using the two-antenna system, frequency selective filters are often used in the antenna feed to the receiver, and in the transmitter feed to the transmit antenna.

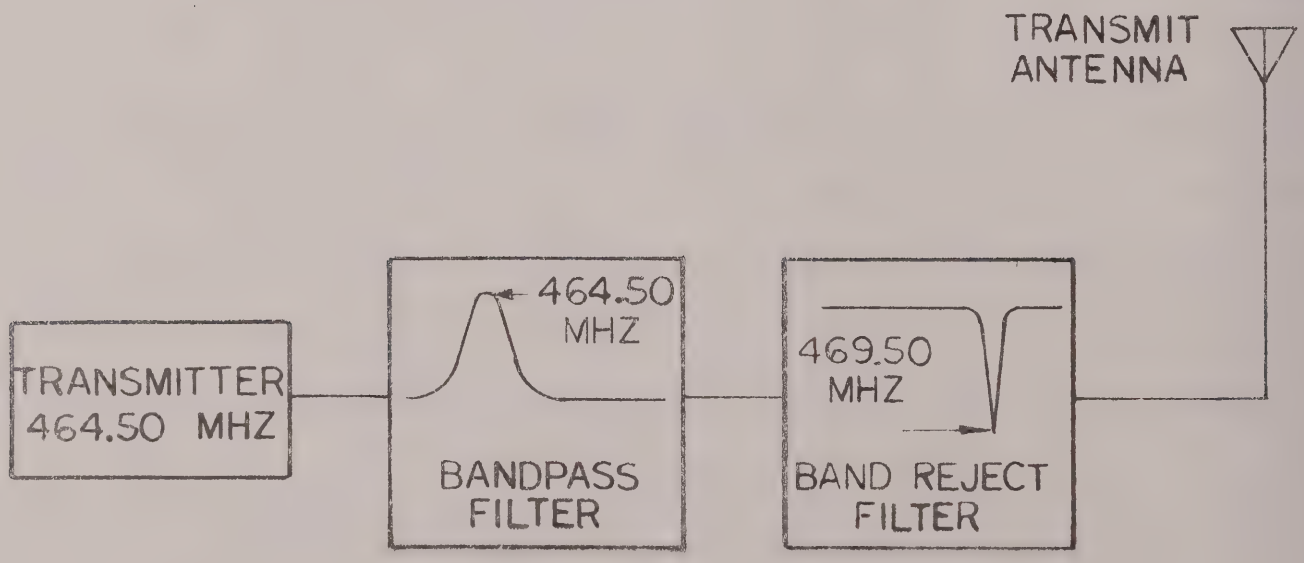
To reduce "Transmitter Carrier Desensitization, we could use two different types of filters: (See Figure 3A) We could put a bandpass type filter, tuned to the receiver frequency in the receiver antenna line. The bandpass filter would allow signals on the receive channel to pass on to the receiver with only slight losses, but would cause great attenuation of energy on the transmit frequency. Alternatively, we could use a band reject type of filter, tuned to reject the transmit channel frequency, and located in the receiver antenna line. The band reject filter would also allow signals on the receive channel to pass with little attenuation, but would cause great attenuation of the transmit frequency. The band reject filter approach is the most effective if we are concerned only with the carrier from one transmitter. However, if we are at a multiple transmitter location, the reject slot is so narrow that it will probably not help block interference from other transmitters at the site. For this reason, the bandpass filter approach is preferred if the site is likely to be used as a multiple site.

To reduce "Transmitter noise interference" with the receiver, we also have the choice of two types of filters. (See Figure 3B) These filters must be placed in the transmit antenna feed line. We



FILTERS IN RECEIVE LINE TO REDUCE
TRANSMITTER CARRIER DESENSITIZATION
OF THE RECEIVER

FIGURE 3A



FILTERS IN TRANSMIT LINE TO REDUCE
TRANSMITTER NOISE INTERFERENCE
TO RECEIVER

FIGURE 3B

could place a bandpass filter tuned to the transmitter channel in the transmitter antenna line. This filter would allow the wanted transmitter output power to be delivered to the transmit antenna with little loss, but would introduce great attenuation of the noise components located in the receive channel. Alternatively, we could locate a band reject filter, tuned to reject the receive frequency, in the transmit line. This filter would cause maximum attenuation to the transmitter noise falling within the receiver channel, but would cause only slight attenuation to all other frequencies, including the wanted transmit frequency. Again, the band reject filter is the most effective if we are concerned with protecting only one receiver channel. However, in a multiple station location, the narrow reject slot would probably protect only one receiver, and leave the other receivers at the site vulnerable to noise from the transmitter. For this reason, again, the band pass filter approach is preferred if the site is likely to be used as a multiple site.

In addition to the choice of using either a band reject or a band pass filter, we also have the possibility of using a combination of both types.

It should be obvious that if we used sufficiently effective filters, we could put the receive and transmit antennas as close together as we wish---we would even connect the two lines together and use only one antenna for both the transmit and receive function,

as shown in Figure 4. This is exactly what a duplexer does. If you look through the various catalogs on duplexers, you will find both bandpass and band reject types. Since band reject filters can be produced smaller, and less costly, than bandpass filters, the reject types are usually smaller and cheaper than the pass types. Either will do the job if there is only one repeater station at the location. However, if you plan to add other repeaters (or stations of any type) at the site, you should go for the bandpass type.

ANTENNA SYSTEMS FOR THE MICRO-COM U10R REPEATER (MOBILE RELAY)

This section is intended to give specific guidance in the choice of antenna systems for use with the Micro-Com U10R Repeater. When we use the term "antenna system" here, we are talking about the antenna(s) itself, the coax line(s), and any filters or duplexers used. Some suitable antenna systems will be itemized for your convenience. In addition, data on the U10R will be given so you can make your own decision about other suitable systems.

On any given repeater, it is possible to give specifications of the attenuation needed at the transmitter frequency between the antenna port and the receiver port of the repeater to avoid "transmitter carrier desensitization" of the receiver. If we have that amount of attenuation--we can obtain it by the use of filters, or by antenna spacing, or both, or by a duplexer--we will not have any degradation of the receiver's performance by the transmitter carrier.

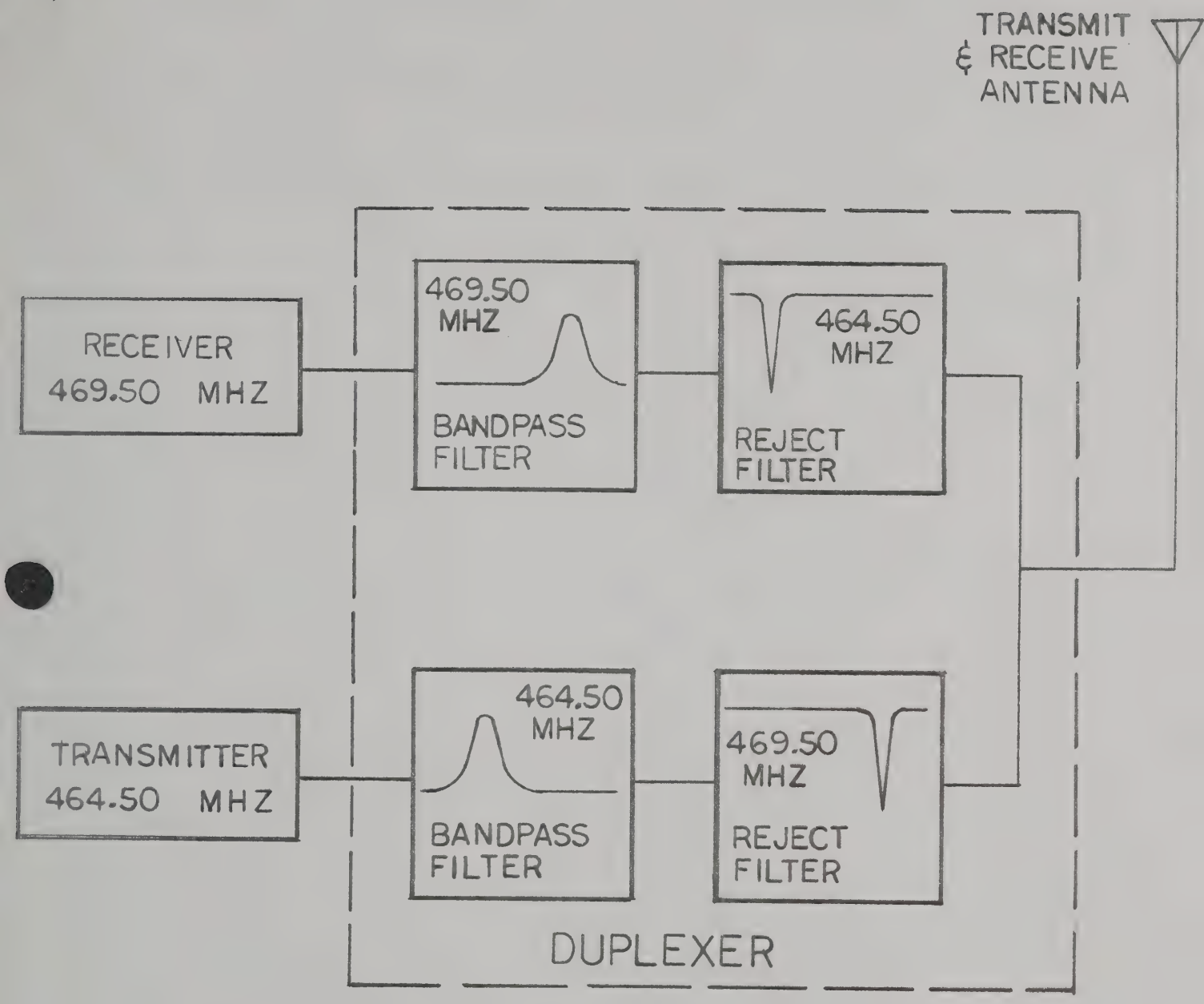

TRANSMIT
& RECEIVE
ANTENNA
RECEIVER
469.50 MHZ
469.50
MHZ
BANDPASS
FILTER
464.50
MHZ
REJECT
FILTER
TRANSMITTER
464.50 MHZ
464.50
MHZ
BANDPASS
FILTER
469.50
MHZ
REJECT
FILTER
DUPLEXER

FIGURE 4

Similarly, it is possible to give a specification on the amount of attenuation needed at the receive frequency between the transmitter and receiver port to avoid "transmitter noise interference" to the receiver. Again, we can obtain this attenuation by the use of filters, or by antenna spacing, or both, or by a duplexer.

Here are the magic figures for the MICRO-COM U10R:

Condition 1: Attenuation needed at the transmitter frequency between receiver and transmitter antenna ports to obtain negligible "transmitter carrier desensitization" of the receiver: 30 DB

Condition 2: Attenuation needed at the receive frequency, between receiver and transmitter ports to obtain negligible interference with the receiver: 56 DB

Using these figures, you can determine whether or not a given antenna system will work without transmitter interference to the system:

Example Number One:

In our system example, let's say that we have determined that we will use a 125' antenna tower, and that it will take an additional 10 feet of antenna cable to reach the equipment. That's 135 feet of cable to reach one antenna--or 270 feet if we use two antennas. It is general industry practice to use an antenna cable that won't lose more than 1½ DB of our transmitted power (or our received signal power) in the length of cable used. 1½ DB means

a power loss of about 30% of the power. If we chose a cable that loses more, we save on the cost of the cable, but we have to balance this against what our R.F. power cost us when we bought our equipment. Anyway, 1½ DB has been used as a pretty good guideline.

Looking through the various cable specifications, we find that 7/8" diameter foam cable has a loss of 1.15 DB per hundred feet, at 450 MHz and that figures out to just a bit over 1.5 DB for 135 feet. We will choose 7/8" foam cable, and will figure our cable loss for one run up the tower to be 1.5 DB.

To make our first example an easy one (and because it might be a good choice for this job), we are going to pick the Decibel Products DB410D antenna, which is really two DB408 antennas mounted on the same mast. Of course, each antenna has its own coax feed line. By properly locating the elements on the antenna, the manufacturer can guarantee 30 DB minimum decoupling between the antennas. (i.e., the attenuation of a signal introduced into the transmit section, and picked up by the receiver section is at least 30 DB.)

This 30 DB attenuation between antennas is going to satisfy our needs for the condition #1 mentioned earlier. In fact, we have the 30 DB attenuation between antennas, plus 1½ DB for each of the two coaxial cable runs, adding up to 33 DB attenuation between the receiver and transmitter antenna ports. This exceeds the 30 DB attenuation needed at the transmit frequency for

condition #1, so we are in good shape on condition #1.

For condition #2, however, we need to obtain 56 DB attenuation at the receive frequency between the receiver and transmitter ports. As mentioned above, we already have obtained 33 DB by the use of the double antenna, and the loss in the coax. We need 23 DB more. We need to put some sort of a filter in the transmit line that will give us this 23 DB attenuation at the receive frequency, with no appreciable attenuation at the transmit frequency.

An economical filter for this purpose is made by Phelps Dodge, with their catalog number 495-509-1.5. When ordered with the 1.5 DB type loops, this filter will give 24 DB attenuation at a frequency of 5 MHz from resonance. This is a pass type filter--the 1.5 DB loops thing refers to the loss at the pass frequency--which in this case would be the transmitter frequency. This 24 DB attenuation, plus the 33 DB we got from the antenna spacing and the antenna cables adds up to 57 DB attenuation at the receiver frequency thereby meeting out condition #2 which requires at least 56 DB.

Now we have an antenna system that meets both of the conditions for avoiding transmitter-receiver interference. How good is it? The DB406 antenna (one half of our special dual antenna) has a rated gain of 6.5 DB. Our coax loses 1.5 DB, for a net antenna gain of 5 DB. We will realize this 5 DB of gain on all received signals, meaning that our 10 watt mobiles will sound as if

they were radiating 31 watts when they are received in the repeater receiver.

We will also realize the same net 5 DB gain in the antenna-coax system on transmit, but the filter needed to meet condition #2 uses up 1½ DB of the transmitter power, leaving a net gain of 3½ DB. Our ten watt repeater transmitter will thus have an ERP (effective radiated power) of 22 watts.

We have now obtained the details of one antenna system, complete with needed filters. We know what it will do, and we should now figure up the costs to see if it is cost effective:

*1 - Decibel Products, DB410 D antenna	$290.00
2 - 135' Runs of 7/8" dia. foam cable	308.00
1 - Phelps Dodge 494-509 filter	55.00
TOTAL COST FOR EXAMPLE NUMBER ONE	$653.00

*These are user prices and not necessarily up-to-date when you read this. We are not figuring such items as antenna brackets, freight and needed coax jumpers in these examples. You should figure them because they add up rapidly.

Example Number Two:

Now, let's compare the system in example #1 with a system using the duplexer approach, and only one antenna.

We'll use the same 125' tower height, requiring 135 feet of cable, so we get a good comparison. We'll plan on using a single DB408 antenna, instead of the dual job used before. Our coax run will therefore have 1.5 DB loss, and antenna will have 6.5 DB gain,

giving a net gain for the antenna and its cable at 5.0 DB.

Since we are using a single antenna for transmit and receive, we need to pick out a duplexer that will meet the Condition #1 requirement of 30 DB isolation at the transmit frequency, and the Condition #2 requirement of 56 DB at the receive frequency.

The Decibel Products model DB4087 mobile type duplexer will more than adequately meet both requirements #1 and #2, since it provides 62 DB isolation at the receive frequency, and 62 DB isolation at the transmit frequency. This duplexer uses reject filters only, and would be satisfactory if we have no other 450 MHz band stations operating at the site.

If we are planning to have other 450 MHz band stations operating at the site, we should choose a filter with some band pass filters. The Phelps Dodge 522-509 duplexer uses a combination of band pass and band reject filters, and would be a good choice for the multiple occupancy site. It meets the requirements of conditions #1 and #2 with generous margins, and has only .4 DB loss in the transmit leg and 1 DB loss in the receive leg. As we shall see later, the band pass filter will cost more money.

Regardless of which duplexer we use, the ERP and receiver signal gains for example #2 are within a DB of those in Example One.

So, here are the costs for Example Number One:

1 - Decibel Products, DB408 antenna	$168.00
1 - 135' Run of 7/8" dia. foam cable	154.00
1 - Decibel Products DB4087 band reject duplexer (optional)	165.00
1 - Phelps Dodge 522-509 bandpass type duplexer	350.00
Total, Example Two with band reject duplexer:	$487.00
Total, Example Two with bandpass duplexer:	$672.00

Which of the two systems should we use on this installation? The answer probably depends upon whether additional repeaters are going to be installed at this site. As the number of repeaters at a multiple site grows, the use of the same antenna for receiving and transmitting on each of the repeaters becomes impractical, and it becomes necessary to cluster transmitter antennas together at one level on the tower, and cluster receiving antennas at a different level. If this is the first repeater at a multiple site, you will want to keep initial costs low, but you should attempt to buy components that will fit into a multiple repeater scheme at a future date.

If you use the two antenna plus pass filter approach (as in example one), each of the antennas can be used and the filters can all be used in the final scheme. If you use the single antenna plus duplexer approach, you should choose duplexers using pass filters if at all possible. The Phelps Dodge 522-509 duplexer mentioned as an alternate for example two is ideal in that the

transmitter leg can be separated from the receiver leg and used separately in the filters in a site having segregated transmit and receive antennas.

There are a lot of other tradeoffs that can be made. For example, one might consider a higher gain antenna(s). The extra antenna gain might be utilized for better system performance, or it might be used to permit use of lower cost coaxial cable. Also---although the single antenna with band reject filter came out the winner on the cost comparison, things would change around if you were at a highrise building or mountain top location and using only a short tower. Suffice to say--figure out a few suitable antenna systems for yourself, and use the one that fits your needs best.

WHAT ABOUT GAIN TYPE MOBILE ANTENNAS?

While we are talking about antennas, we should say something about the mobile antennas. They are just as important as the ones sitting at the top of the repeater station tower.

One of the big benefits of the 450-512 MHz band is the fact that we can get substantial antenna gains in reasonable sized (and therefore reasonable cost) antennas. Gains of 6 DB and more are readily available for the antennas at the repeater, and mobile antennas with gains of 3 to 5 DB are available for mobiles at prices of about $20.00.

5 DB of antenna gain makes your 10 watt mobile "look like" a

30 watt mobile with a simple 1/4 wave antenna. It also has the same effect as increasing your mobiles sensitivity from the rated .35 microvolts to .2 microvolts.

If you add up the costs, there is probably nothing sillier from a cost point of view than a 30 watt, 450 MHz mobile running about with a standard 6", 1/4 wave whip!

For this reason, you should definitely use good, gain type, mobile antennas.

While we are talking about mobile antennas, there is no location like the center of the car roof for a 450 MHz antenna. Locate the antenna there if you can.

THE CONTROL STATION ANTENNA

Usually, the control station is located within a few miles of the repeater station--or at least well within the mobile coverage of the repeater. For this reason, it is not necessary to make a fancy control station antenna location.

The major complicating factor regarding the control station antenna comes from FCC rule 91.554 (B) (9). This rule applies if the control station is located "less than 75 miles from the center of any urbanized area of 200,000 or more population." In that event, the control station antenna must be a directional one with at least 15 DB front to back ratio. This requirement is easily met with almost any of the lower cost Yagi antennas, and some dealers use a cheap UHF TV antenna with 75 ohm coax feed for the

purpose. Once you have provided the directional antenna, you usually have no need to invest in any fancy coax to feed it. In fact, you may want to use the cheapest RG58/U cable, and make an unusually long run of cable! Why? Well, once you install the control station, you must go through the following procedure to satisfy rule 91.554 (B) (9)---To quote the rule directly:

> (9) Control stations associated with mobile relay stations may be authorized to operate on the land mobile service frequency assigned to the associated mobile station. However, when located less than 75 miles from the center of any urbanized area of 200,000 or more population such stations must emply directional antennas having a front-to-back ratio of at least 15 DB and may radiate a signal that, when measured at the antenna terminals of the mobile relay station receiver, does not exceed the signal strength of a mobile station operating from the control station location by more than 6 DB. To make this measurement the mobile station may be moved no more than one-fourth mile away from the control location if necessary to provide a satisfactory signal at the mobile relay receiver. An engineering statement attesting to compliance with this signal level limitation shall accompany each control station application. Urbanized area of 200,000 or more population are defined in the U.S. Census of Population, 1960, Vol. 1, table 23, page 1-50. The centers of urbanized area are determined from the appendix, page 226 of the U.S. Commerce publication "Air Line Distance Between Cities in the United States." Control stations authorized prior to June 1, 1968, must conform to this requirement no later than November 1, 1971.

LOOK HOW THOSE ANTENNA DBs ADD UP:

We've spent a great deal of time on antennas, but I really want to emphasize how proper attention to antennas will make your 10 watt repeater and your 10 watt mobiles act like real powerhouses.

Although we didn't quite reach it in our two antenna examples,

a net antenna system gain of 5 DB at the repeater is quite practical and mobile antennas with 5 DB of gain are readily available. That adds up to 10 DB, which stated another way, means a power gain of ten times. Our 10 watt repeater station "looks like" a 100 watt station to the mobile receivers. And our 10 watt mobiles "look like" 100 watt units to the repeater station receiver.

WHAT ABOUT POWER AMPLIFIERS?

There are a lot of power amplifiers on the market that can be used to boost the repeater transmitter power to higher levels---and there are also amplifiers that are suitable for mobile use. In general, I don't think much of them, because I think that the dollars invested could be put to better use in higher towers and higher gain antennas.

Since local noise pickup is comparatively negligible at 450 MHz, it doesn't help the system much just to increase the power at the base station (repeater)--in most cases you want to talk both ways, and this would mean power amplifiers at each end. A balanced 450 MHz system should use the same power at the repeater station that it uses at the mobiles.

If you have a special case, however, these amplifiers do provide an inexpensive way to increase the repeater power.

A WARNING

IF YOU ADD A POWER AMPLIFIER WITH A GAIN OF, SAY, 10 DB, YOU MUST ADD 10 DB TO THE CONDITION #1 AND CONDITION #2 figures given

back in the section on transmitter-receiver interference at the repeater station. This means better filters, or more antenna spacing. Figure these in when you are determining the real cost of the power amplifier.

REPEATER RANGE EXPECTATIONS:

Now, I am going to go out on the limb and give you a list of what you might expect in the way of range of a repeater station at 450 MHz. Take these with a grain, or better yet a full dose, of salts. Terrain conditions, vegetation, and a lot of other factors can give you some surprises. It is a good idea to make judgment about expected range based upon the experience of other 450 MHz stations in the area. You can also get a fair idea from knowledge of 150 MHz stations in the area. Be conservative on your first station, so all of the surprises are good ones!

The following table assumes:

1. Micro-Com U10R used as the repeater station. 10 watts output and .35 microvolts receiver sensitivity.

2. A total effective antenna system gain (including filter and duplexer losses) of 5 DB at the mobile relay station.

3. Micro-Com U11 mobiles. 10 watts output, .35 microvolts sensitivity.

4. 5 DB gain mobile antennas.

5. Distance given is radius of coverage area from the repeater station. Maximum mobile-to-mobile range will be twice this value.

REPEATER STATION RANGE

HEIGHT OF LOWEST REPEATER STATION ANTENNA	REPEATER RANGE
50 feet	25 miles
100 feet	29 miles
150 feet	32 miles
200 feet	33 miles
250 feet	37 miles

SOURCES:

If you are serious about 450 MHz repeaters, you should get the catalogs of the prominent antenna and duplexer/filter suppliers on hand. These catalogs give a lot of valuable information, including the expected attenuation between horizontally and vertically spaced antennas. Here is a list of a number of the prominent suppliers.

1. Andrew Corporation
   10500 W. 153rd St.
   Orland Park, Illinois 60462
   (312) 349-3300
   — Antennas, Coaxial Lines, Duplexers

2. Antenna Specialists Co.
   12435 Euclid Avenue
   Cleveland, Ohio 44106
   (216) 791-7878
   — Antennas, Coaxial Lines

3. Decibel Products, Inc.
   3184 Quebec Street
   Dallas, Texas 75247
   (214) 631-0310
   — Antennas, Coaxial Lines, Duplexers, Filters

4. Phelps Dodge Communications Co.
   Route 79
   Marlboro, New Jersey 07746
   (201) 462-1880
   — Antennas, Coaxial Lines, Duplexers, Filters

5. Larsen Antennas — Mobile Antennas
   11611 N.E. 50th Ave.
   Vancouver, WA 98663
   (206) 573-2722

6. Sinclair Radio Laboratories — Antennas, Duplexers, Filters
   P.O. Box 23
   Tonawanda, New York 14150
   (716) 874-6383

The following companies make add-on power amplifiers for 450 MHz band:

1. TPL Communications, Inc. — Power Amplifiers
   13125 Yukon Ave.
   Hawthorne, Calif. 90250
   (213) 679-0131

2. Dynamic Communications — Power Amplifiers
   948 Ave. "E"
   Riviera Beach, Florida 33404
   (305) 844-1323

Information to help you fill out license application forms and frequency coordination forms for mobile relay stations in the business radio service will be supplied in the near future. This information has had to be delayed because of pending changes in the forms.